Evaluating and tuning a single column model with CloudSat/CALIPSO

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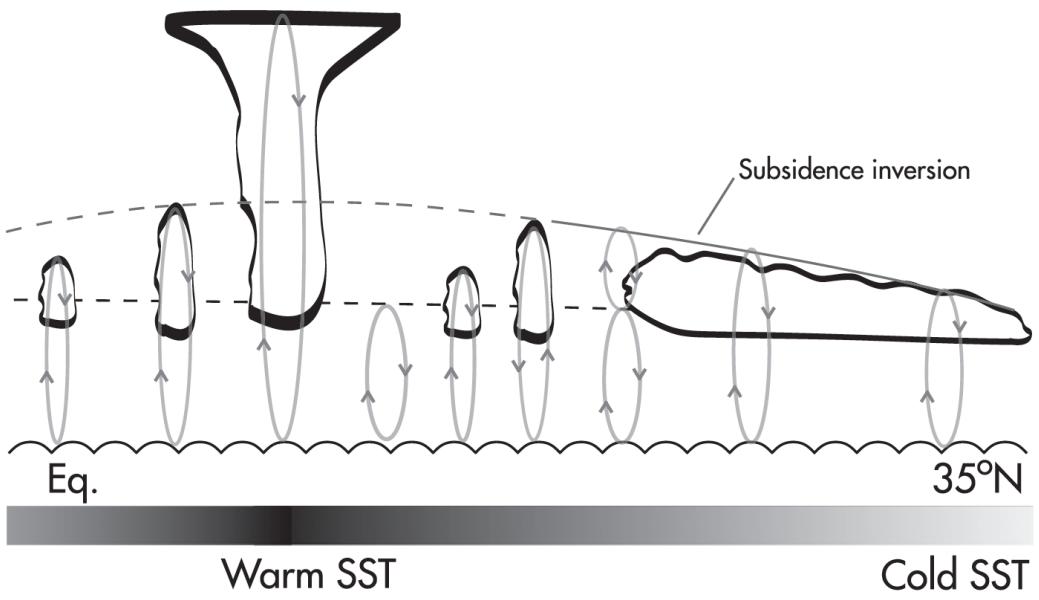
Global Models Struggle to Produce Realistic StCu - Cu Transition

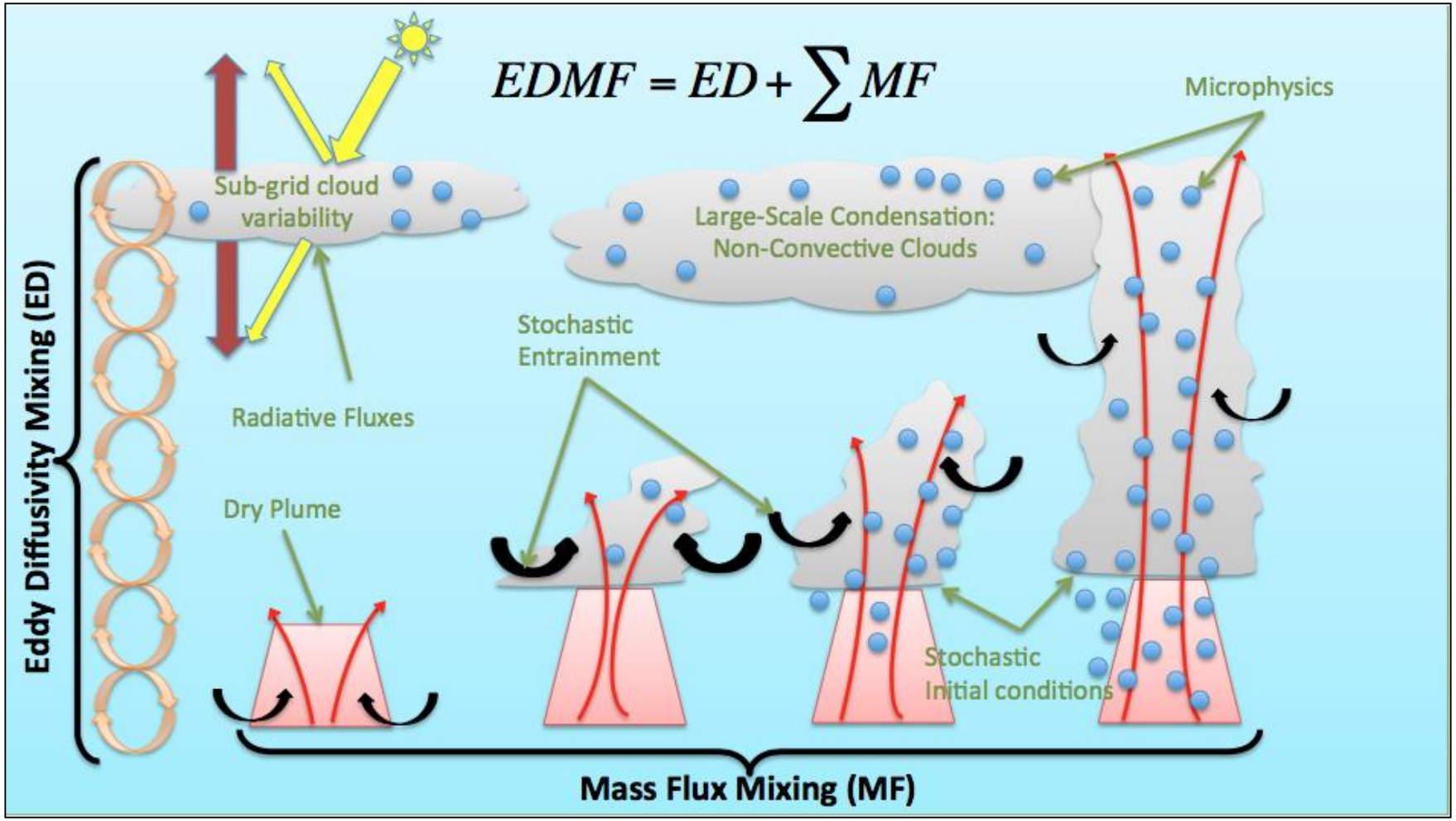
- Typical problem is “too few – too bright”
- Realistic simulation requires smooth transition from well-mixed cloudy MBL to cumulus-coupled layer.
- Typical parameterization schemes for boundary layer and shallow convection are discrete. This does not realistically represent the gradual nature of the transition.



Karlsson et al., 2010

The JPL Eddy-Diffusivity/Mass-Flux (EDMF) Parameterization

- EDMF contains all parameterized atmospheric processes: mixing, radiation, microphysics
- Prognostic QT, THL, and horizontal winds
- Unified physics represents shallow convection and turbulent boundary layers



In This Study

- We evaluate the EDMF (as a single column model) against satellite observations of the StCu-Cu transition with initial conditions from weather reanalyses
- Advantage over LES: large number of cases capture real (noisy) weather
- Advantage over GCM: computationally cheap, allows exploration of parameter space
- Disadvantages: initial conditions, forcings, and observations are uncertain

Single Column Model

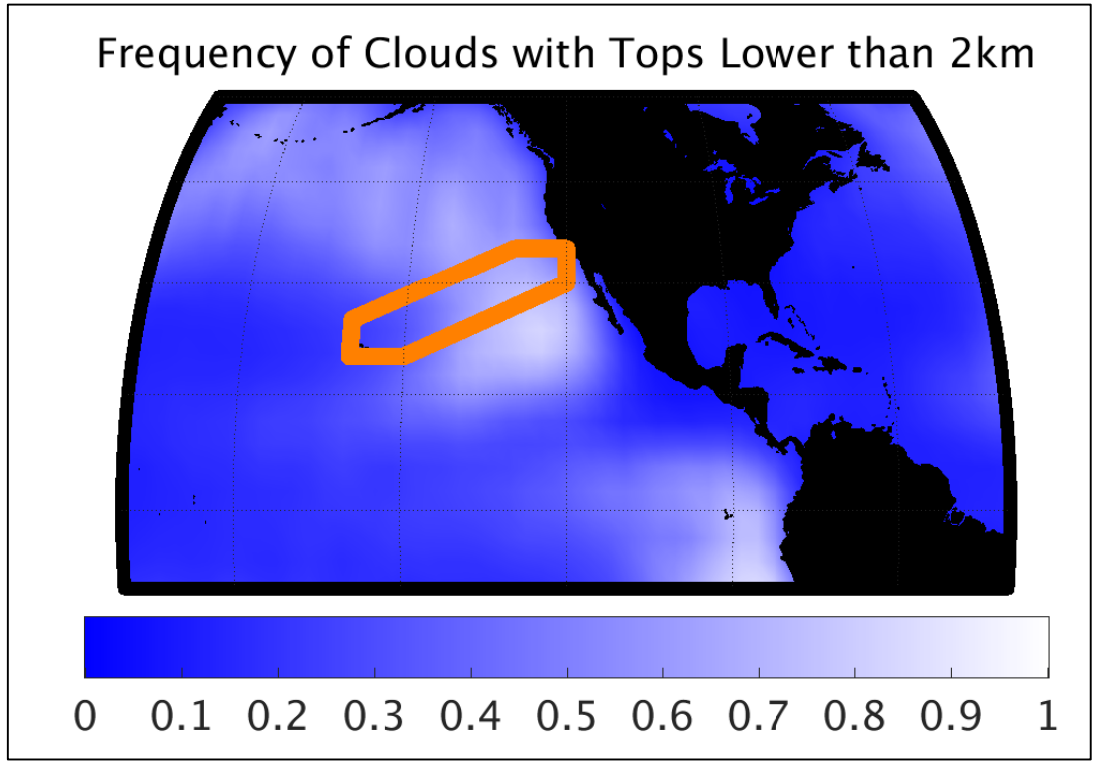
dz = 20 m
dt = 30 s
Domain 0-20 km
0.5° x 0.625° (MERRA2)

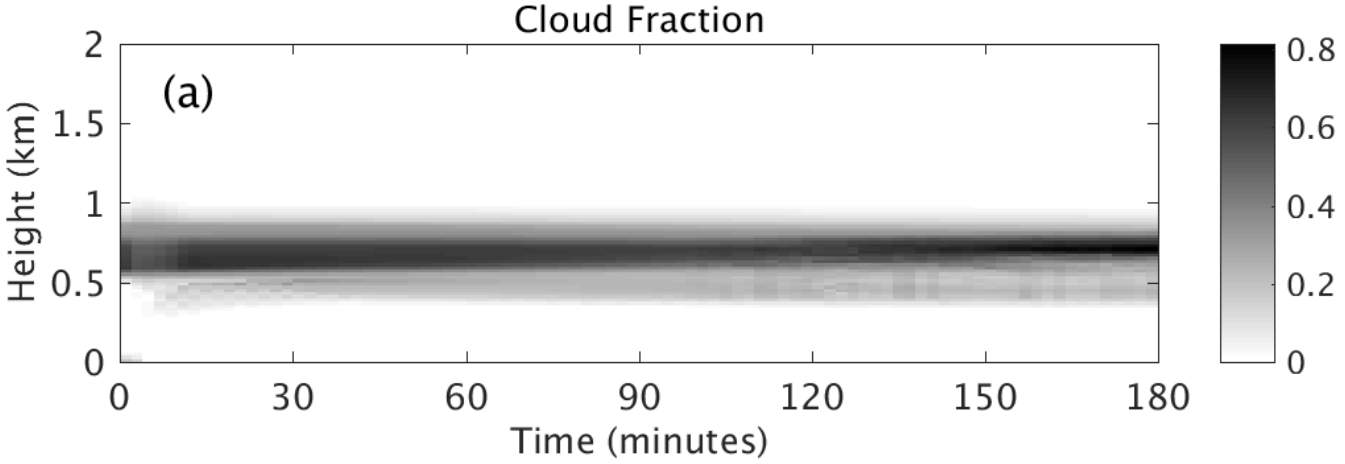
Data

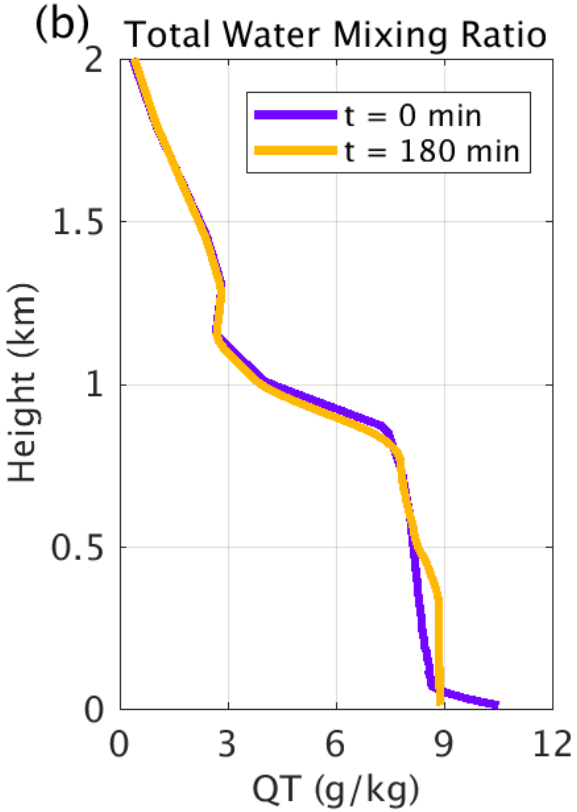
1000 profiles in JJA 2007
OMEGA500 > 1 mbar/hr
2B-GEOPROF-LIDAR

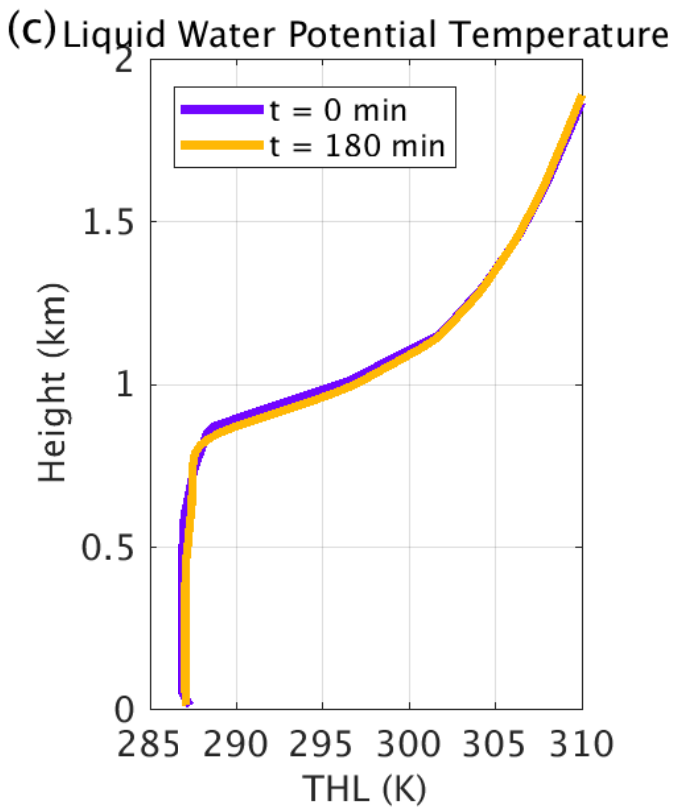
Simulation and Evaluation Framework

- Initial conditions from MERRA2, three hours before observations are made.
- Surface fluxes are read from MERRA2
- Currently, tendencies from advection are not applied.
- Model is run until time of CALIPSO/CloudSat overpass



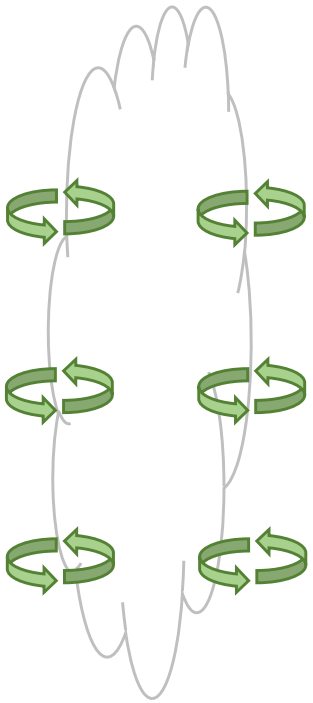


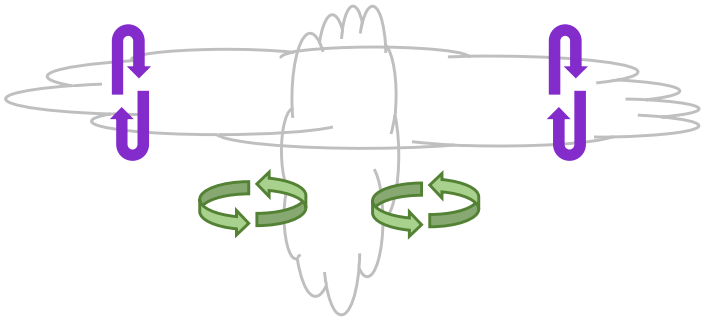




- ✓ Stable StCu layer
- ✓ Inversion lowers and strengthens
- ✓ Well-mixed boundary layer

Parameters Controlling Stratiform and Cumulus Cloudiness

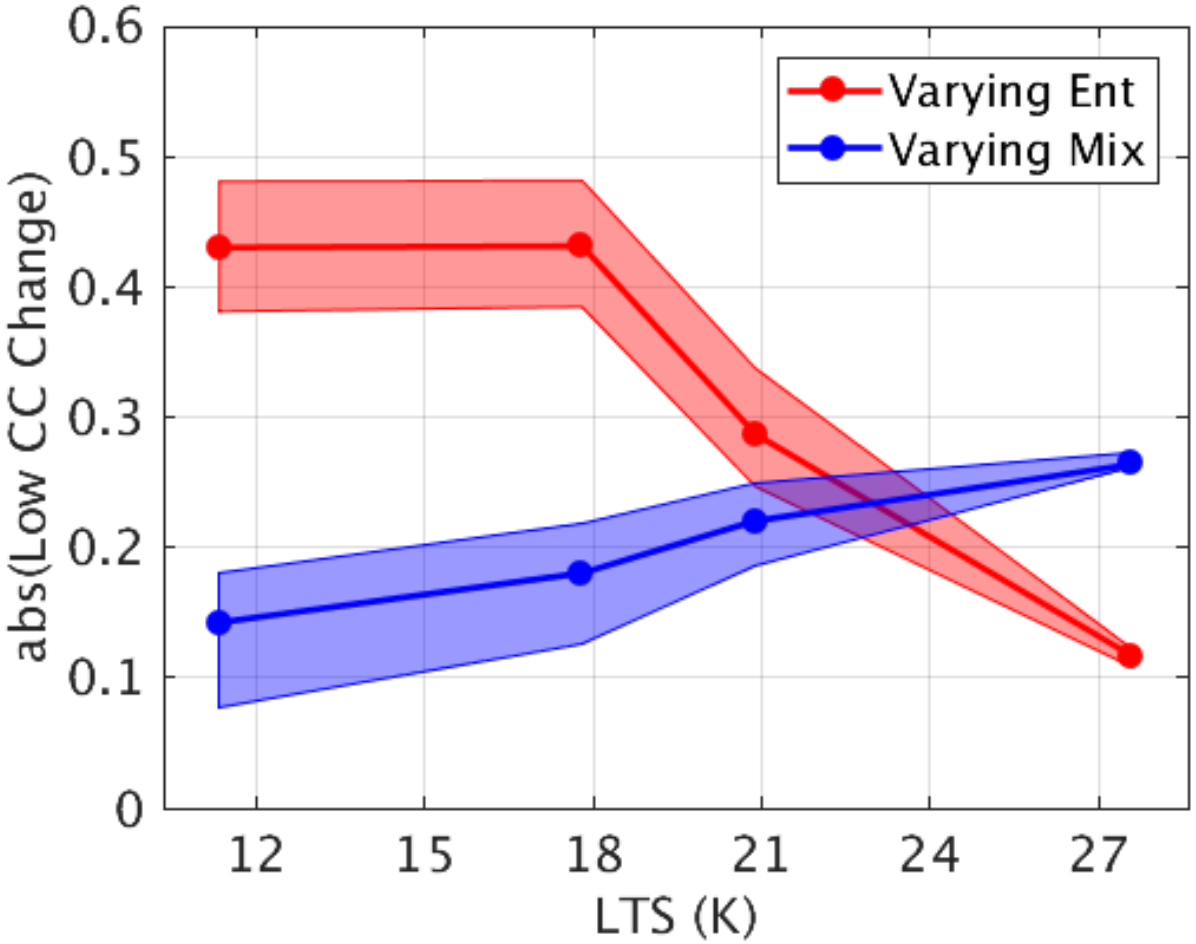




Parameter “Mix” controls Turbulent Mixing

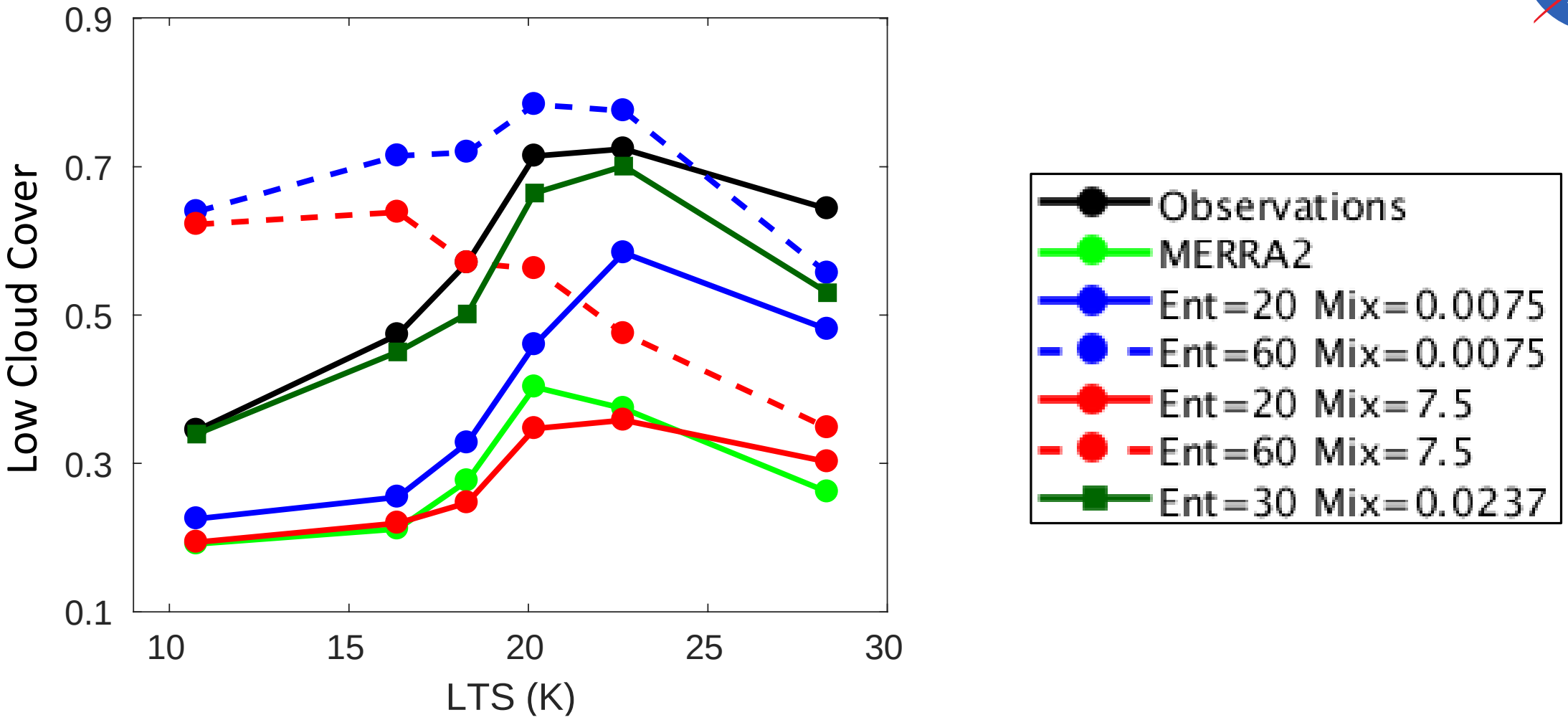
Parameter “Ent” controls Lateral Entrainment

Effects of “Mix” and “Ent” on Simulated Cloud Cover



- “Ent” affects Cloud Cover in unstable conditions
- “Mix” affects Cloud Cover in stable conditions

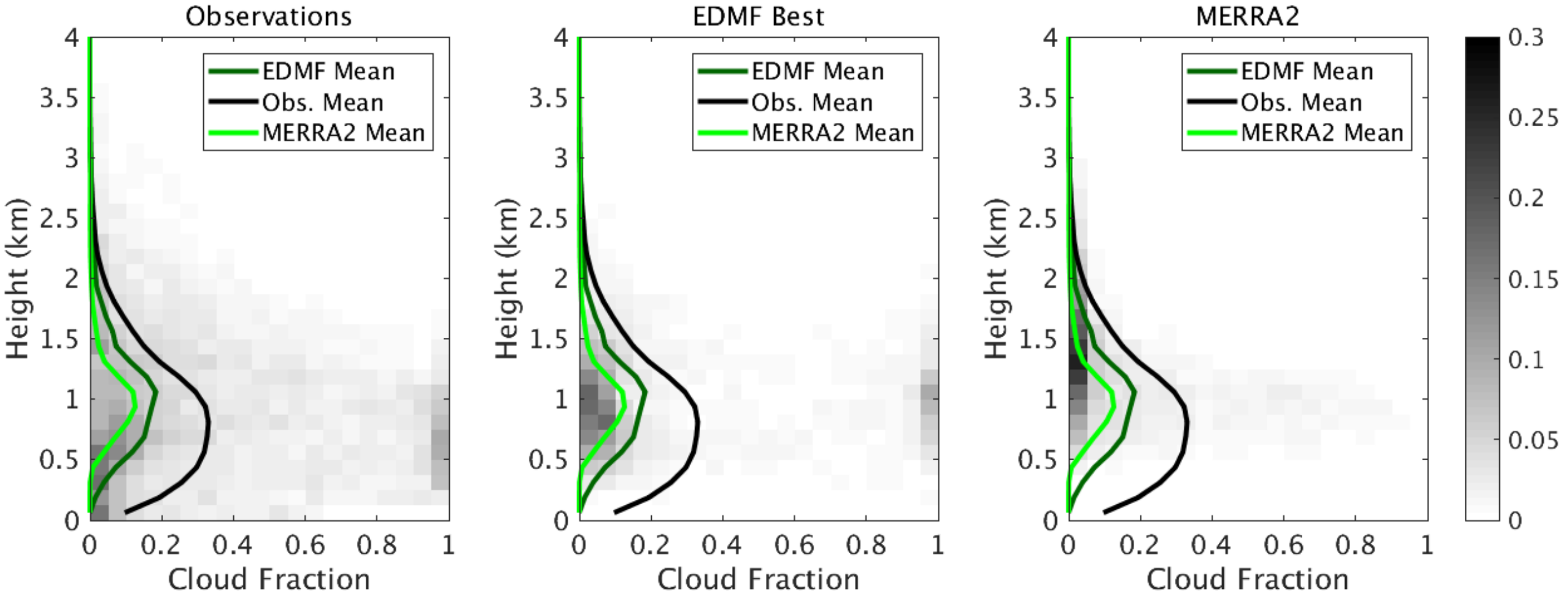
Selecting the “Best” Parameter Combination



We select Ent=30m, Mix=0.01 as the best combination.

PDF of Vertical Profile of Cloud Fraction

- JPL EDMF produces 100% cloudiness despite deficient initial conditions from MERRA2.
- Underestimate of average cloud fraction means JPL EDMF clouds are too geometrically thin.



Conclusions

1. Vertically-resolved observations of cloudiness from CALIPSO/CloudSat provide a reliable testbed for turbulence parameterizations without the need for costly LES runs or over-training to specific weather regimes.

2. The right combination of both small-scale turbulent mixing and updraft lateral entrainment are necessary for an accurate depiction of the transition from cumulus to stratocumulus cloud conditions.

3. Simply assessing the mean cloud cover would not produce the correct cloud cover as a function of stability.

Thank You

Karlsson, J., and Coauthors, 2010. Subtropical Cloud-Regime Transitions: Boundary Layer Depth and Cloud-Top Height Evolution in Models and Observations. *J. Appl. Meteorol. Climatol.* **49**, 1845-1858.

Sušelj, K., J. Teixeira, and D. Chung, 2013. A Unified Model for Moist Convective Boundary Layers Based on a Stochastic Eddy-Diffusivity/Mass-Flux Parameterization. *J. Atmos. Sci.* **70**, 1929-1953.

Sušelj, K., J. Teixeira, 2018. A unified eddy-diffusivity/mass-flux approach for modeling atmospheric convection. In Review.

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Cal/Val of Turbulence Parameterizations

LES/Field Campaign

- ✓ Widely known and repeatable
- ✓ High resolution budgets of non-observables important to turbulence parameterizations (e.g. mixing lengths, entrainment)
- ✓ Extensive observations of important/characteristic weather regimes

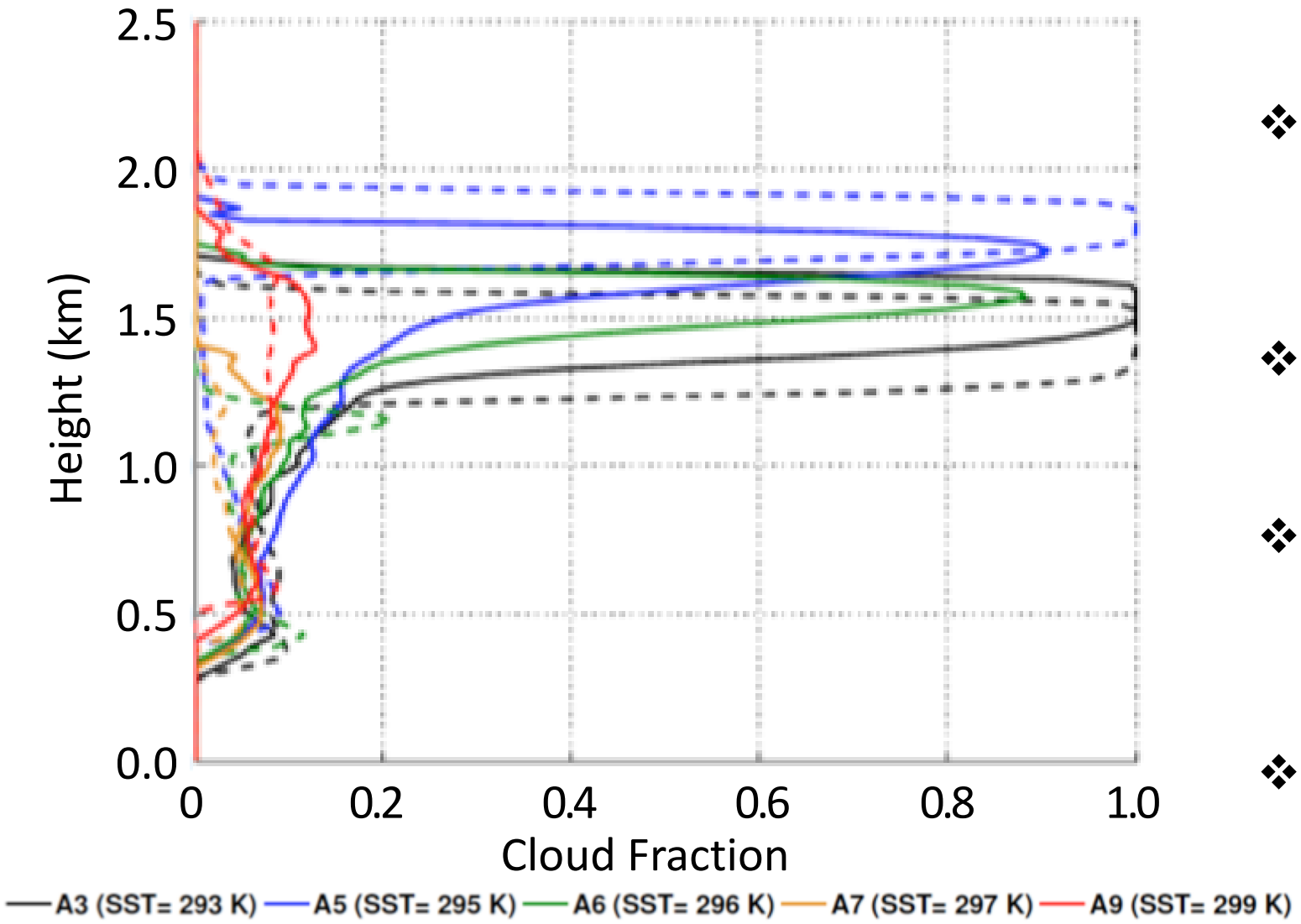
- ○ Over-train simulations with selection-biased weather regimes
- ○ Difficult to disentangle errors from turbulence parameterization from errors in 3-D simulations
- ○ Initial conditions are often idealized and smoothed.

Observations/Reanalysis

- ✓ Globally-available
- ✓ Column simulations isolate errors in turbulence parameterization from 3-D advection.
- ✓ Simulations of real, noisy weather conditions

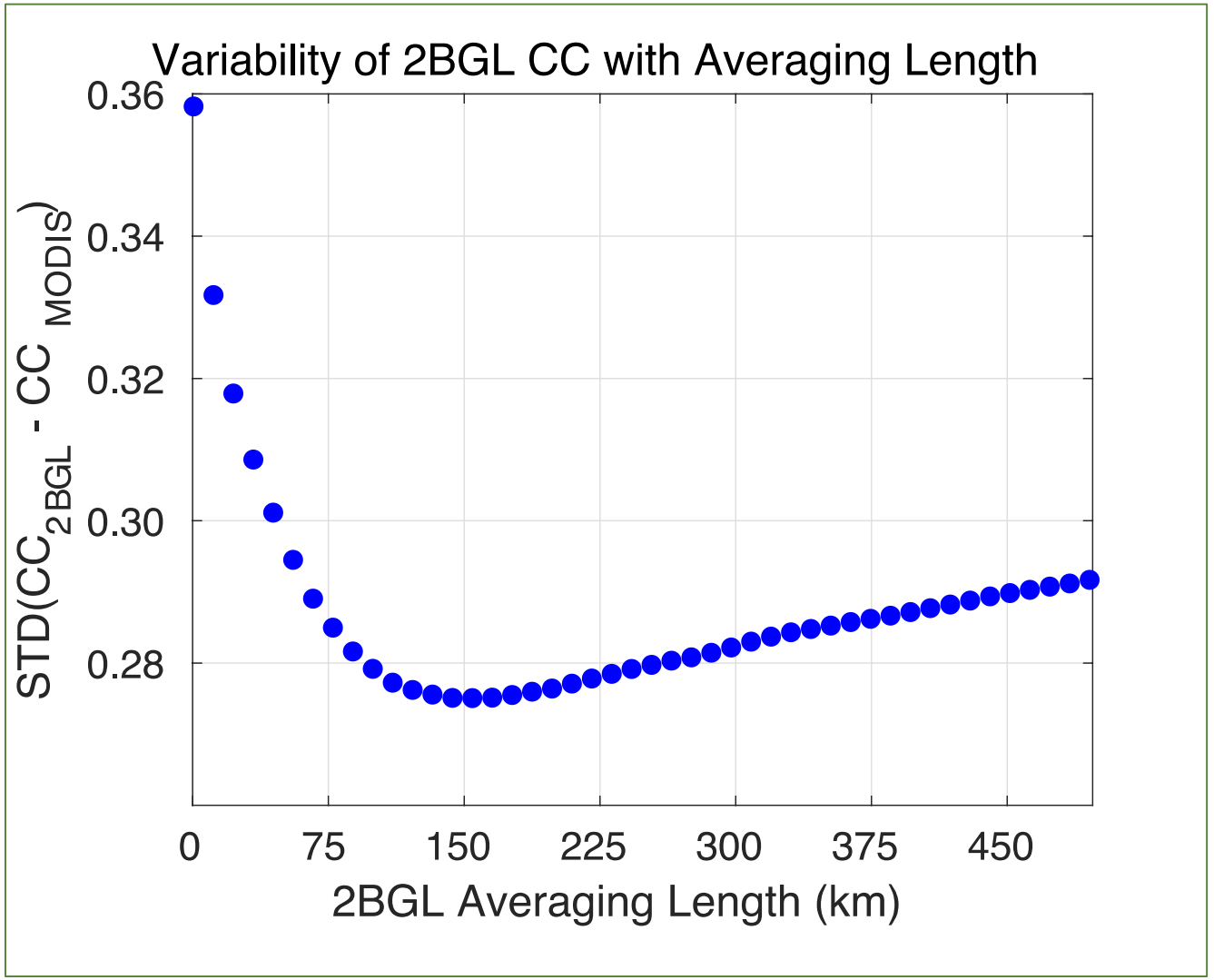
- ○ Observations are limited, carry their own uncertainties, and are comparatively coarse resolution.
- ○ Sensitive to the quality of initial conditions.

EDMF Initially Tuned to LES Simulations



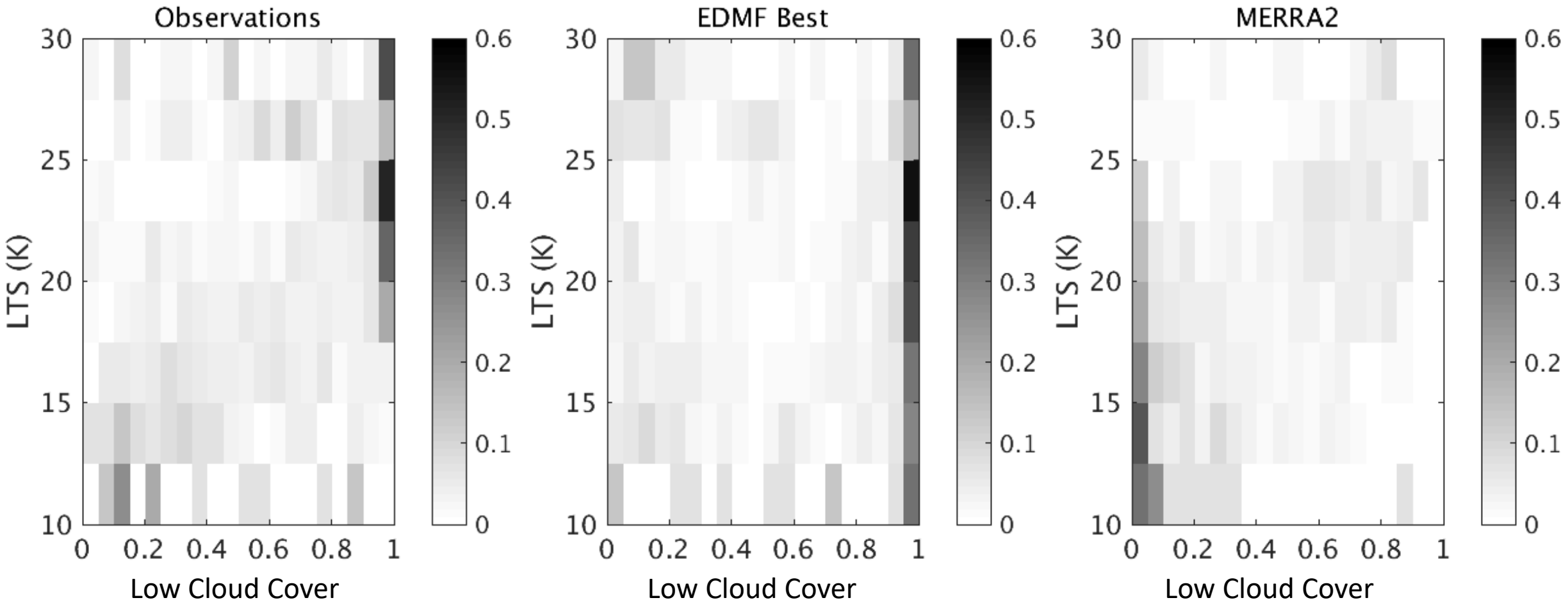
Sušelj et al. (2013)

- EDMF is tuned to reproduce LES simulations of turbulent fluxes and cloudiness.
- LES provides a comprehensive evaluation of a single case
- LES shown here are meant to approximate the StCu – Cu subtropical cloud transition.
- *Is comparison against a few idealized simulations sufficient?*

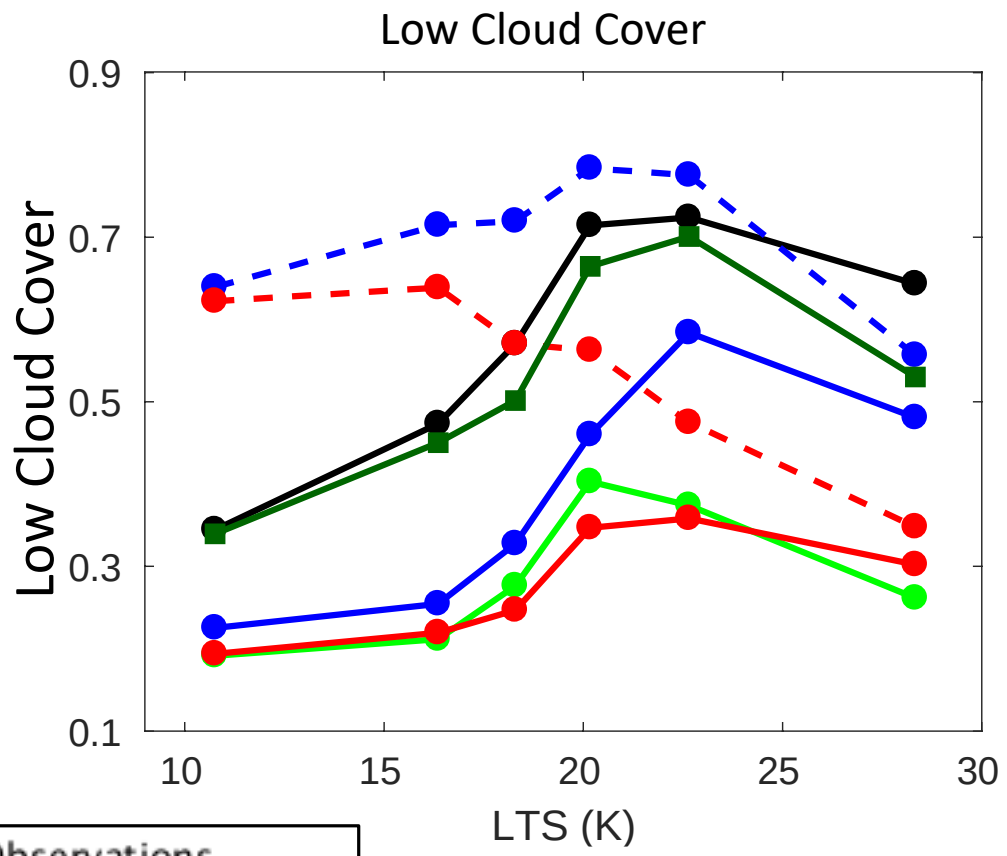

Variability of 2BGL CC with Averaging Length
0.36
0.34
0.32
0.30
0.28
STD(CC2BGL - CC MODIS)
0
75
150
225
300
375
450
2BGL Averaging Length (km)

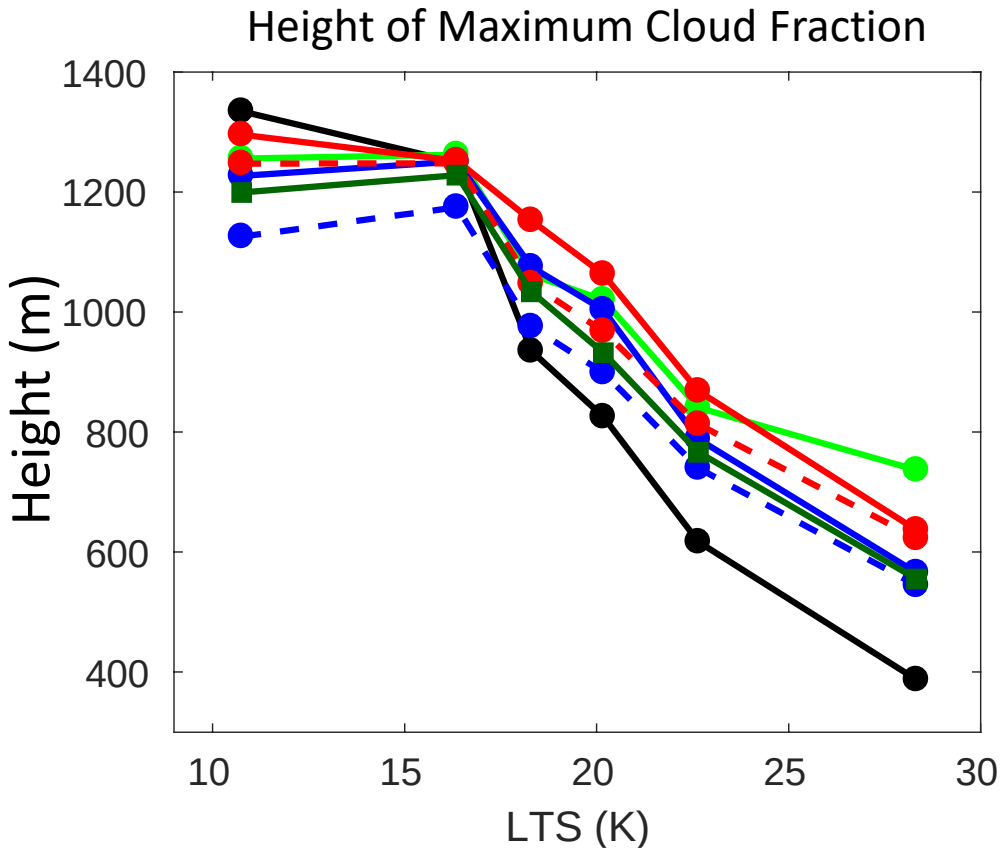
PDF of Low Cloud Cover as Function of Stability Regime

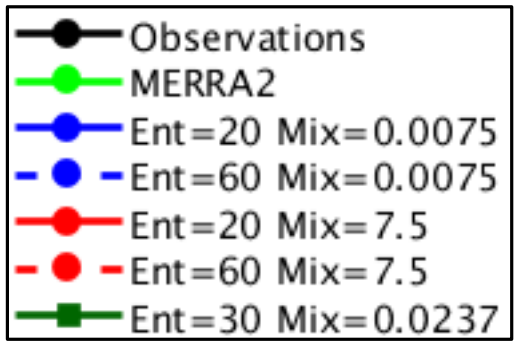
- JPL EDMF captures the transition of cloudiness across stability regime, but also frequently produces 100% cloudiness when LTS is low.



Selecting the “Best” Parameter Combination







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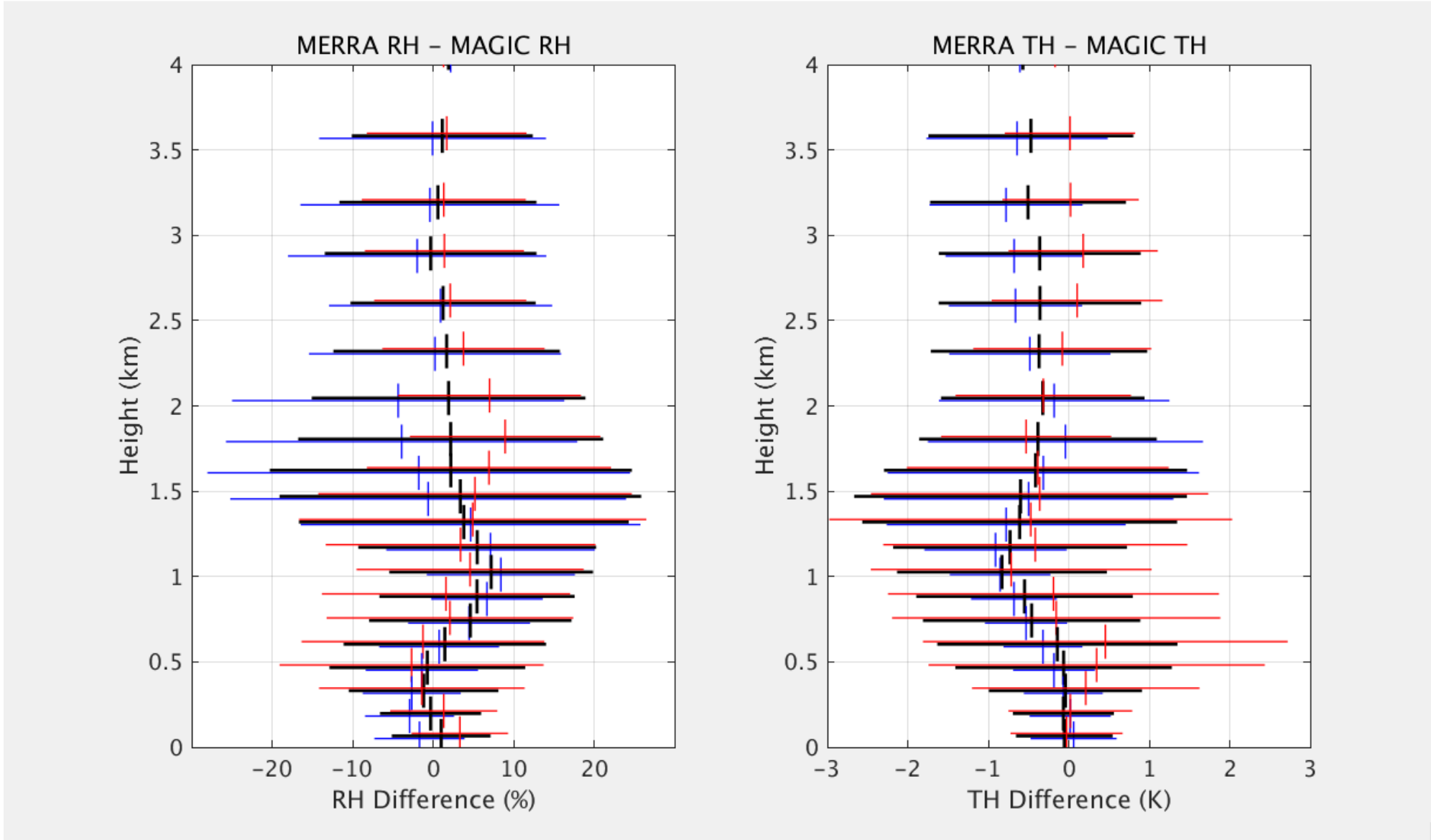
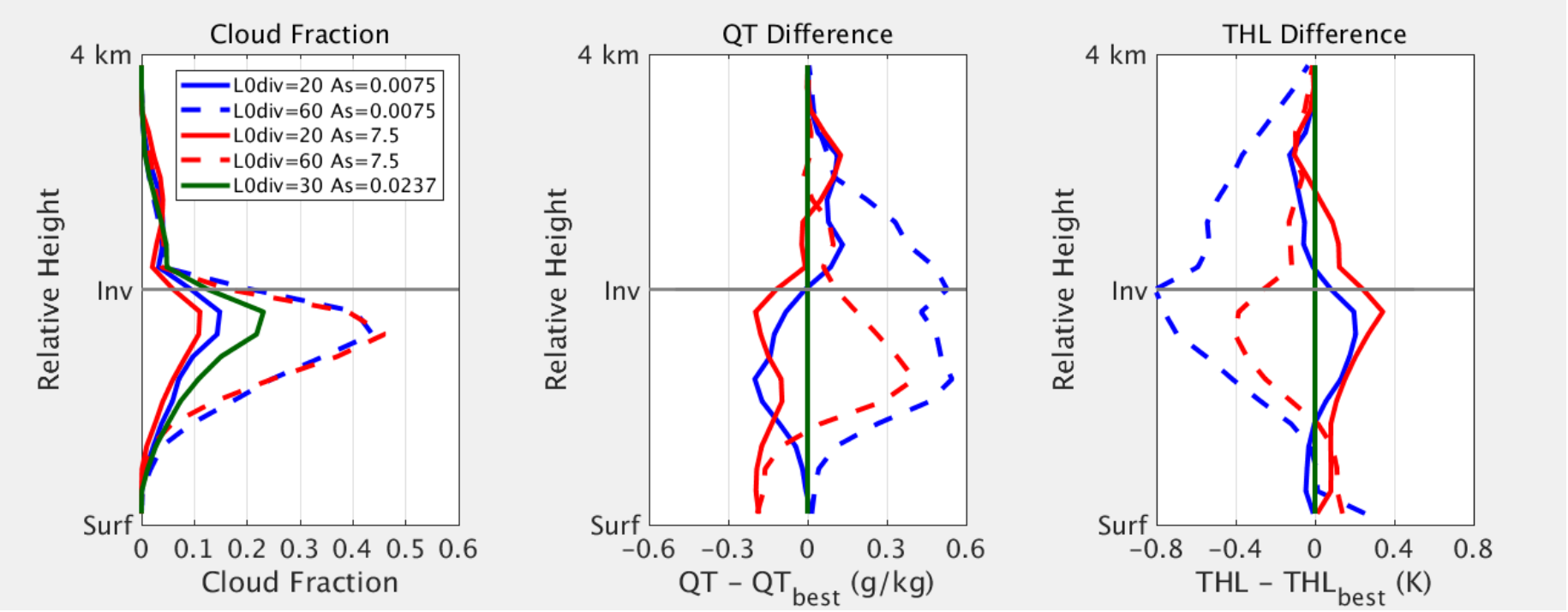
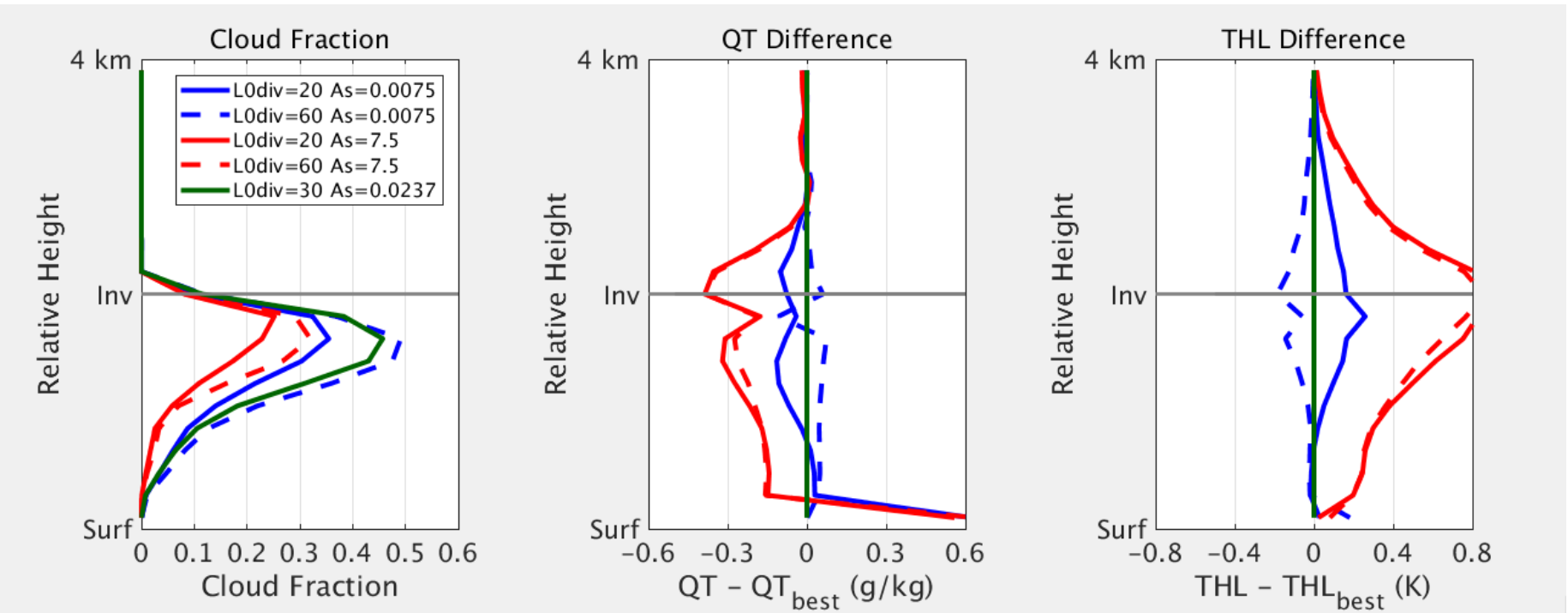

MERRA RH – MAGIC RH
Height (km)
RH Difference (%)
0
0.5
1
1.5
2
2.5
3
3.5
4
−20
−10
0
10
20
MERRA TH – MAGIC TH
Height (km)
TH Difference (K)
−3
−2
−1
0
1
2
3



Lower quartile of LTS



Upper quartile of LTS